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OBSERVATIONS ON THE REFRIGERATION OF SOME ILLINOIS FRUITS IN TRANSIT

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OBSERVATIONS ON THE REFRIGERATION OF SOME ILLINOIS FRUITS IN TRANSIT[a]

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For many years southern Illinois has produced considerable quantities of fruits and vegetables intended primarily for Chicago and other nearby markets. Direct rail transportation from the producing regions to these markets enabled the growers to harvest their products and place them on the market in twenty-four to thirty-six hours. Under such conditions good fruit required few special precautions to insure its arrival in good condition. Increased competition has forced Illinois producers to seek new and more distant markets for their products. Wider distribution of Illinois grown commodities has brought about handling problems that were foreign to the short-haul business prevailing in former years. Fruit in carlots has frequently arrived in the markets overripe or decayed, with consequent losses to the producers.

The most perishable commodities regularly shipped in carlots from Illinois are strawberries, peaches, and summer apples. When investigations were begun in 1926 with the object of seeking solutions of the problems concerned in the handling and transporting of Illinois perishables, the above mentioned commodities were selected as logical materials for these studies. Special attention has been given to certain phases of the refrigeration of these fruits in transit. A portion of the results obtained from these investigations are here reported.

DISCUSSION OF THE LITERATURE

Considerable literature has appeared from time to time dealing with the general subject of refrigeration in transit and with many of its separate phases. Much of this has been published as reports, either formal or informal, of experimental work along these lines. Discussions based on personal opinions or general experience are by no means rare. Space does not here permit nor do circumstances warrant a complete discussion of the literature pertaining to refrigerated transportation of fruits and vegetables. This discussion is therefore confined largely to reports on actual experimental work having a direct bearing on the subject. No attempt is made to consider new or unusual schemes for refrigerating railway cars.

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[a]The tests here reported were conducted with the cooperation of the Illinois Central Railroad Company.

Much of the work relating to the refrigeration of perishables in transit has been done by the U. S. Department of Agriculture. Many tests, however, have been conducted by railroads and by private car lines, but most of the results thus obtained have never been made public and are therefore not available to the general reader.

Ripening and Rot as Related to Temperature

Gore[7*] found that fruits respired much more rapidly at high than at low temperatures, and that for 49 sets of determinations with 40 different kinds of fruits the rate of respiration increased an average of 2.376 times for every 10° C. rise in temperature. Gandy strawberries doubled their rate of respiration with an 8.2° C. rise in temperature. Elberta peaches did the same with an 8.4° C. rise, and Yellow Bellflower apples with a rise of 9.7° C. Gore also found that little or no change in the rate of respiration of the peach was produced by picking. Magness[11*] reported that apples respired about twice as rapidly at 40° F. as at 32° F. At 60° F. respiration was three times as fast as at 40° F.

Hawkins and Sando[8*] found strawberries and other small fruits to be much less resistant to mechanical injury at 75° to 80° F. than the same varieties of fruits at 55° to 60° F. Rose[22*] reported that over a period of four years the fungus Rhizopus caused 58 percent of all rots of strawberries on the market. He also reported[23*] that blue-mold rot occurred more commonly than any other rot of apples on the market.

Stevens[24*] reported that the most common and destructive disease of strawberries in transit was caused by the common black mold, *Rhizopus nigricans,* Ehrb. He stated that this mold usually gained entrance to the berry thru wounds, and that it grew very slowly at temperatures below 50° F. Stevens and Wilcox[25*] reported that *Rhizopus nigricans* was unable to puncture the sound epidermis of the strawberry. These workers found that the rate of growth of Rhizopus was very slow at 50° F. but increased rapidly above that point. Temperatures of 45° F. and below practically prevented any growth in this organism. They also found that atmospheric humidity had no perceptible influence on the rate at which *Rhizopus nigricans* rotted strawberries. Their work clearly indicates that temperature is the limiting factor in the development of this disease, and that its critical temperature lies between 45° and 50° F.

Brooks and Cooley,[2*] working with apples, found that blue-mold was effectively held in check if the fruit was cooled immediately after infection, but that it was not greatly inhibited when the fruit was not placed at low temperature immediately after inoculation. The same authors,[3*] working with peaches, found that temperatures of 50° F. held brown rot in check for one or two days, and held Rhiz-

opus rot in check for three days. Temperatures of 45½° F. held brown rot in check for three days and Rhizopus in check for six or more days. Peaches stored at 45½° F. immediately after inoculation were five days slower in developing brown rot than those delayed one day at 77° F. and then stored at 45½° F.

Brooks and Cooley,[4*] working under commercial shipping conditions, found that with needle-inoculated fruit every hour's delay in getting the fruit loaded put the brown rot in the top layer of the car more than three hours ahead and that in the bottom of the car five hours ahead. These authors reported that in the case of Rhizopus rot of peaches, a delay of ten to fifteen hours in loading may mean the difference between no infection and 20% to 100% infection. The importance of rapid refrigeration is emphasized by their findings that 60% of the damage due to brown rot in transit in either the top or bottom of the car took place during the first 36 hours after the car was closed.

The above results indicate the importance of immediate and rapid cooling of fruits and vegetables after picking if overripeness is to be prevented and rots are to be held in check.

Rapid Cooling Essential

The efficiency of refrigerator cars in cooling loads of fruits and vegetables has been the subject of much study by the United States Department of Agriculture and by railroads and refrigerator car lines. Powell,[17*] working with California oranges, found that careful handling to prevent injury was the first essential to successful shipment of this fruit. He also found that prompt shipment lessened decay, and that precooling retarded the development of rot. Stubenrauch[26*] found that decay of Florida oranges was largely dependent on the handling of the fruit during harvesting and packing. He also found that precooling helped to retard rot development. Ramsey[18,19*] pointed out that with red raspberries, cherries, and fresh prunes careful handling was the first essential to successful shipment, and that prompt and rapid cooling was necessary if the fruits were to be shipped long distances. Ramsey and Marshall[20*] found that non-precooled lettuce and celery took four days to reach the temperature that precooled cars maintained from the start. Temperatures were much more uniform thruout precooled cars than unprecooled cars. The authors also reported that precooling and initial icing for a long haul were more satisfactory and less expensive than shipping celery under standard refrigeration without precooling.

Winterrowd[27*] discussed in considerable detail the factors of importance in refrigerator car construction and their influence on refrigeration of the lading. He pointed out that refrigeration is accomplished by naturally circulated air cooled by contact with ice. Cool-

ing may be hastened by using salt with the ice, according to Winterrowd, but the effect of brine dripping on mechanical equipment such as bridges and insulated joints presents a serious problem.

Salt as an Aid to Refrigeration

Salt as an aid to rapid cooling has been mentioned by many investigators. Pennington,[14*] recommended about 9 percent salt at initial icing and a little less at re-icings. She made these recommendations for such ladings as cantaloupes and oranges if a car with basket bunkers, solid insulated bulkheads, and floor racks were used. In another article[15*] she recommended salting the ice with 1 to 3 percent or more at initial icing and at the first two re-icings. She stated that the air issuing from the bunkers of a well built standard refrigerator car has a temperature of about 34° F., and that in commercial practice this temperature will fall 1° F. for each percent of salt added to the ice at initial icing.

It is of interest at this point to note the work of Wright and Taylor[28*] on the freezing temperatures of certain fruits and vegetables. These investigators found that summer apple varieties froze at an average temperature of 28.44° F., peaches at 29.41° F., and strawberries at an average of 29.93° F.

McKay[12*] reported that cooling was considerably hastened by salting the ice in the bunkers immediately after loading, and added that salt should never be used in cars not equipped with floor racks, solid insulated bulkheads, and basket bunkers. McKay, Fischer, and Nelson[13*] recommended adding 5 to 8 percent of salt at the first application in shipping melons if the temperature of the lading was over 80° F., with less salt for lower temperatures. Ridley,[21*] working with strawberries, found that a car equipped with floor racks and which had 2½ percent of salt added to the ice in the bunkers, cooled the lading much more rapidly than a car in which salt was not used and which was not equipped with floor racks.

Refrigerator Car Equipment

Types of bunker and bulkhead equipment in refrigerator cars have been studied by several investigators. Pennington[14*] reported that cars equipped with basket bunkers, floor racks, and solid insulated bulkheads were much more efficient than equally well insulated cars equipped with box bunkers, open bulkheads, and without floor racks. She did not state what part of this increased efficiency was contributed by each of these separate factors. Other data presented by her[16*] may be interpreted as indicating that there is no great difference in performance of cars equipped with box bunkers and those equipped with basket bunkers, if both cars are equipped with floor racks and solid insulated bulkheads. Ridley[21*] reported

that false floors aided strawberry refrigeration, but his data indicate that this effect was not outstandingly great. McKay reported that cars equipped with open bulkheads and not equipped with floor racks refrigerated cantaloupes more slowly than cars equipped with solid insulated bulkheads and floor racks. No attempt was made to isolate the effects of these equipment features.

Importance of Air Circulation

Discussions of the importance of rapid air circulation within the cars are found in most works on refrigerator car efficiency. Pennington, in several articles, mentioned the need of loading in a manner to allow rapid circulation of the air. Hill, Graham, and Wright[9*] found that too tight loading of celery retarded air circulation within the car and prevented efficient refrigeration. They found[10*] that temperature differences between lading in various parts of the car were accentuated when air circulation became choked thru poor car construction, faulty loading, or the shifting of the load. Andrews[1*] stated that when air is the cooling medium, over fifty cubic feet are required to remove one heat unit from the fruit if a one degree rise in air temperature is produced. This does not take into consideration any cooling that may be produced by evaporation.

Considering the importance of air circulation within refrigerator cars, very little intensive work seems to have been done on this subject. Evans and Griffith[5*] reported that they traced the air currents in end-ice-bunker refrigerator cars by means of smoke. They gave no detailed description of the work but stated that air currents within the cars leave stagnant air spaces. Gibson and Graff[6*] studied the air circulation in refrigerator carloads of box apples under ventilation and in box cars loaded with apples, but reported no work on cars under refrigeration. McKay[12*] found that the practice of moving cantaloupe cars with the ventilators slightly opened during the first night in transit apparently did not affect the refrigeration, but he did not study the effect on the air circulation within the cars. A few air circulation tests have been made in refrigerator car models, but apparently no results of great significance have been reported thus far.

PLAN OF EXPERIMENTS

Refrigeration tests were conducted on carloads of strawberries, Yellow Transparent apples, and peaches during the summers of 1926, 1927, and 1928. These cars were shipped as nearly as possible under ordinary commercial conditions. The variable factors in the tests will be discussed later.

Refrigerator cars used in the tests were taken directly out of active service. They were identical in design and construction, being

insulated with the same type and quantity of insulating material and equipped in all cases with the same type of bunkers. Bulkheads were of the solid insulated type.

All cars were inspected before loading, and were found to be in good condition. Doors and bunker plugs fitted tightly in all cases, and drain pipes were dripping freely. The sides, floors, and ceilings of these cars were in good condition. There were no breaks in the walls inside or outside, except in one car which had a small break in the outside layer of lumber near the door. Floor racks were present or absent as noted in the detailed description of the conditions of each test.

Usual Methods of Loading Employed

In all tests with strawberries the fruit was packed in American 24-quart ventilated crates loaded 4 layers high, 7 rows wide, and 15 stacks long, making a total of 420 crates to the car.[a] The crates were stripped with lath stripping. Laths were placed across each end of the crates, and the next layer of crates was placed on the laths. In no cases were the strips nailed to the crates.

Peaches were packed in bushel baskets and were loaded in the cars 3 layers high and 6 rows wide, with 22 baskets in each layer of each row, making a total of 396 bushels to the car. The end-to-end offset method of loading bushel baskets was followed in all cases.[b]

Yellow Transparent apples were packed in bushel baskets. A full load consisted of 528 baskets loaded 4 high, 6 wide, and 22 long, according to the end-to-end offset loading method.[c]

Temperatures of Shipments Compared

Fruit shippers at Illinois producing points do not often send two cars of one commodity to any given market the same day. Because of this it was usually impossible to run tests on two or more cars simultaneously. This was unfortunate in that cars shipped on different dates were not subjected to identical weather conditions. An examination of the data obtained from 14 tests conducted during 1926, 1927, and 1928, however, indicated that the outside air temperatures, even when extremely high or unusually low, had no appreciable effect on the rate of cooling of fruit within the cars. Undoubtedly cars of fruit picked and packed at the same time and shipped to one market in the same train are best suited to com-

[a]A minimum carload of Illinois strawberries is 17,000 pounds. Loaded as indicated, a car contains slightly above that minimum.

[b]A minimum carload of Illinois peaches is 20,000 pounds. A car loaded as indicated contains somewhat more than that minimum.

[c]A minimum carload of Illinois apples in bushel baskets is 24,000 pounds. A carload of 528 baskets contains considerably more than that minimum.

parison. But inasmuch as all of the cars used in these tests were identical in construction and were equally well insulated, and since outside temperatures appear to have very little effect on the rate of cooling of the fruit, it is believed that comparisons can reasonably be made between the various tests here reported.

The work of Gore and of Magness, as previously pointed out, showed that temperature is the factor controlling the rate of ripening after fruits are removed from the parent plant. Brooks, Cooley, and others, as mentioned above, showed that other things being equal the rate of rot development is determined by the temperatures to which the fruits are subjected. Because temperature conditions of fruit in transit have such important effects on rate of ripening and on rot development, and because of the extreme difficulty of evaluating the influences of growth conditions and other complicating factors found in commercial shipment of fruits, it was thought best to confine these studies to the temperature changes found at various points thruout the cars under certain conditions of shipment. Therefore baskets of fruit in which thermometers were placed were not always of exactly the same degree of ripeness, altho care was taken that the fruit in these baskets was approximately at the same stage in the ripening process and was free from decay as nearly as could be determined by superficial examination. No attempts were made at the end of the tests to compare the stages of ripeness of the fruit in the different positions, but it was examined for freedom from decay. Whenever decayed specimens were found in close proximity or in immediate contact with the thermometers, notes were made to that effect.

Electrical Resistance Thermometers Used

All records of fruit temperatures within the cars were taken with electrical resistance thermometers similar to those used by the United States Department of Agriculture in tests on refrigeration in transit. This equipment permitted temperatures to be secured at twelve different locations inside the car. Cables from the bulbs or sensitive points of the thermometers joined a master cable. A part of the master cable in the form of a thin plate passed between the door and door frame to the outside of the car (Fig. 1). Temperature records were taken from the end of the master cable, which was fastened to the roof of the car. Before each test the thermometers were checked against a mercury thermometer known to be accurate within .5° F.

When temperatures of peaches or apples were being taken, the thermometer bulbs were forced directly into the flesh of large specimens of the fruit. In each case these fruits were located approximately in the middle of the basket at a point 6 inches below the cover. The baskets were placed in selected positions in the car as they were loaded. When strawberries were under test, the thermom-

eter bulbs were placed in the centers of the quart boxes with the berries packed firmly around them. These boxes were located in the middle of the top layer in crates placed in selected positions thruout the load.

Locations of Thermometers in Car

Experimental work done at this station[a] has shown that refrigeration is practically the same at similar points in opposite ends of

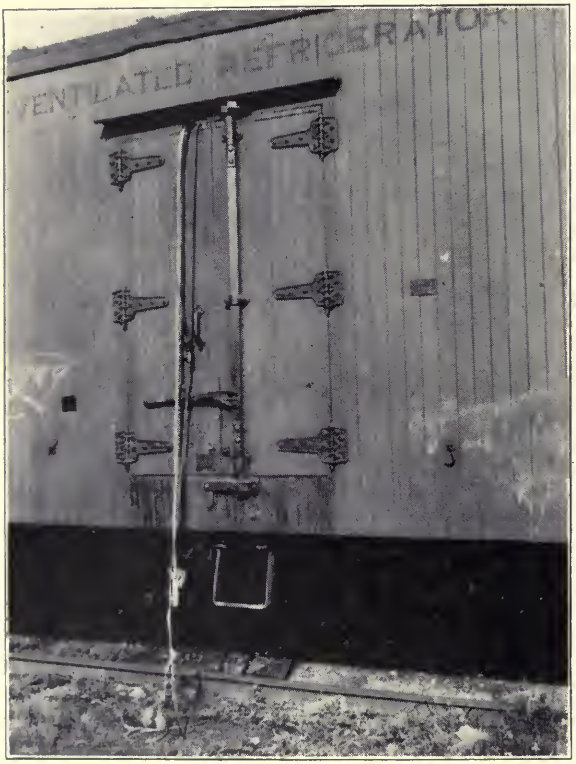

FIG. 1.—POWER CABLES AND ELECTRICAL THERMOMETER CABLES ENTERING REFRIGERATOR CAR

The part of the master cable that passes between the door and the door frame is in the form of a thin plate.

refrigerator cars, provided lading, package types, and loading systems are similar in the two ends of the car. Therefore thermometer readings were, as a general rule, taken only in one end of the car.

[a]Unpublished data, 1926.

In most cases the positions selected were in the middle row running lengthwise in the car. Thermometers were placed in top and bottom tiers in the stack against the bunker, in the quarter-length stack or that midway between the bunker and the middle of the car, and in the door stack midway between the car ends. Occasionally thermometers were placed in the row against the car wall in positions comparable to those selected in the middle row. In other cases thermometers were placed only in the middle row but were placed in

FIG. 2.—TAKING TEMPERATURE READINGS

The temperatures at 12 points inside the refrigeration car were read by the aid of special equipment attached to the thermometer cable outside the car.

all tiers in the bunker, quarter-length, and door stacks. The locations of the thermometers in each car are shown in the tables for the given car.

Thermometers in the quarter-length stacks are in equal proximity to twice as many baskets of fruit as those in the bunker and door stacks when one half of the car is considered as a unit. Therefore a simple numerical average of the temperatures recorded in these six positions probably is not a true average of the temperature thruout the car. A more accurate average is represented by the formula $A = \frac{Bt + Bb + 2(Qt + Qb) + Dt + Db}{8}$, where B represents the bunker stack, Q the quarter-length stack, D the door stack, t the top tier, and b the bottom tier. Unless otherwise stated, this

formula has been used in calculating all averages reported in this publication.

Temperature Records Taken at Intervals

As soon as loading was completed and the cars closed the initial temperature records were taken (Figs. 2 and 3). In a few cases cars were held over night on track with not enough fruit to com-

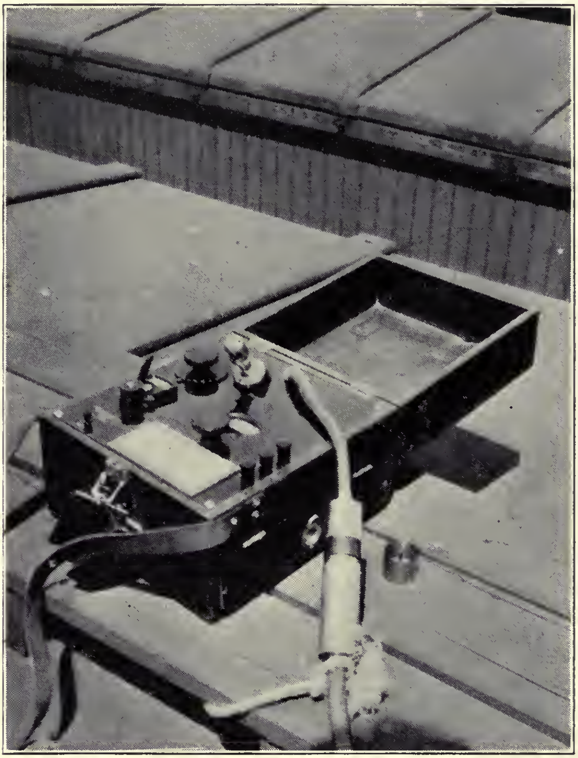

FIG. 3.—CLOSE VIEW OF APPARATUS USED IN TAKING TEMPERATURE READINGS

plete the load. In such cases the initial temperatures were taken as soon as the cars were closed for the night, and notes were made describing the actual happenings.

Temperature readings were taken at as near 3-hour intervals as possible during the early part of the trips, and as often as practicable toward the end of each test. Outside air temperatures were taken whenever fruit temperature readings were made. At such times

notes were also made as to direction and general velocity of wind, sunshine, and precipitation. The temperature records were supplemented by reports from the United States Weather Bureau concerning air temperatures for the dates and regions thru which the cars passed while in transit.

Records of ice supplied the cars while in transit were, in most cases, obtained at the time the cars were iced. In a few cases where this was not done the complete records were supplied by the railroad company.

Method of Constructing Tables

The tables illustrating refrigerator car performance were constructed in the following manner. The original temperature readings for each position in every car were plotted graphically on 17-by-22-inch cross-ruled paper. These sheets were ruled five squares to the inch. The temperature records for each car were plotted on separate sheets. Temperature differences were plotted vertically, each 1/5-inch square representing one degree Fahrenheit. Time differences were measured horizontally, each 1/5-inch square representing one hour. From these charts the temperatures at all points were calculated at 12-hour intervals following the first temperature reading. The drops in temperature during the 12-, 24-, 36-, 48-, 60-, and 72-hour intervals following the initial temperature readings were then calculated for each position in all the cars and were tabulated in the form herein presented. When temperature drops during the first few hours of the test differed considerably from those observed later in the tests, figures showing comparative rates of cooling during the first 6 hours are included in the tables.

RESULTS OF THE TESTS

Most of the fruits and vegetables shipped in carlots from Illinois producing points are in transit between two and five days. Furthermore, Illinois shipments requiring less than two days in transit are more common than those requiring more than five days to reach their destination. Brooks and Cooley have shown that, from the standpoint of disease control, rapid cooling during the first few hours in transit is of very great importance. The effects of rapid cooling on the rate of ripening of fruits have been pointed out by Gore, Magness, and others.

The rates of cooling of fruits during the first 48 hours in transit are therefore of the most interest to Illinois shippers. In the discussion of data obtained from these experiments particular attention has been paid to the rates of refrigeration observed during the first two days of the tests.

Floor Racks Caused More Uniform Cooling of Peaches

Car A, Without Floor Racks. Car A was a refrigerator car in good condition but without floor racks which, for this test, was iced in the regular commercial way about seven hours before loading began. It was then sent by local freight to a shipping point in southern Illinois, where it was spotted for loading.

The lading for the test on Car A was 396 bushels of Elberta peaches packed in bushel baskets and stowed in the car according to the end-to-end offset system of loading. This fruit was picked be-

TABLE 1.—COMPARISON OF TEMPERATURES IN DIFFERENT PARTS OF CAR A, WITHOUT FLOOR RACKS, AND CAR B, WITH FLOOR RACKS
(Both cars loaded with peaches)

Car	Thermometer Positions			Starting temperature	Drop in temperature		
	Stack	Layer	Row		In 12 hours	In 24 hours	In 36 hours
				° F.	° F.	° F.	° F.
A	Bunker	Bottom	Middle	64.5	14.8	21.8	25.2
B	Bunker	Bottom	Middle	67.5	14.0	22.2	25.8
A	Bunker	Top	Middle	69.5	9.3	19.9	26.8
B	Bunker	Top	Middle	73.0	4.2	10.5	14.8
A	Quarter-length	Bottom	Middle	68.0	10.0	15.2	19.2
B	Quarter-length	Bottom	Middle	71.5	11.8	19.8	23.5
A	Quarter-length	Top	Middle	67.5	3.2	6.8	10.7
B	Quarter-length	Top	Middle	73.0	5.8	12.5	16.3
A	Door	Bottom	Middle	69.0	8.6	11.7	14.7
B	Door	Bottom	Middle	72.5	13.7	20.8	25.9
A	Door	Top	Middle	71.5	3.2	5.7	9.5
B	Door	Top	Middle	72.0	3.2	7.7	11.8
A	Average	......	......	68.3	7.8	12.9	17.0
B	Average	......	......	71.6	8.8	15.7	19.7

fore noon of the day on which the test began. It was hauled directly from the orchard to a packing shed where it was packed and hauled a short distance to the car. Loading began about 11:30 a.m. and was completed at 3:15 p.m. the same day. At 6:15 p.m. the car began the trip to Detroit, Michigan. During the loading period the car doors were left open only while fruit was being put into the car.

Thermometers used in the test were placed in the fourth row (one of the two middle rows). The exact positions of the thermometers within the row are described in Table 1. As soon as loading was completed, the car was closed and sealed, and the initial temperature readings were taken. Succeeding temperature readings were taken at as near three-hour intervals as possible. Toward the end of the test the length of these intervals was increased to eight to ten hours.

Cloudy weather prevailed during the day on which this test was begun. Air temperatures were moderate for August, the thermome-

ter recording 76.5° F. at 3:25 p.m. Slightly lower temperatures prevailed during the morning. Fruit loaded into the car varied in temperature from 68° F. to 73° F., with most of it about 70° F.

This car was unloaded in Detroit, Michigan, early in the morning of the third day, approximately 60 hours after the beginning of the test. Records shown in Table 1 cover only the first 36 hours because of circumstances which made the final readings in Detroit unreliable.

Car B, With Floor Racks. Car B was a refrigerator car built according to the same specifications as Car A, but was equipped with floor racks. It was initially iced in the usual way about 9 hours before loading began. It was then sent to the packing shed for loading.

Three hundred ninety-six bushels of Elberta peaches in bushel baskets constituted the load on which this test was conducted. As in Car A, the baskets were stowed according to the end-to-end offset system. The fruit was picked during the morning and was hauled

TABLE 2.—ICING RECORD OF CARS A AND B

Car	Icing	Ice	Salt	Time from first temperature reading
		lbs.	*lbs.*	*hrs.*
A	Initial	9 000	0	11 before
	First re-icing	6 000	0	14½ after
	Second re-icing	1 800	0	30½ after
	Total	16 800	0	
B	Initial	9 000	0	8 before
	First re-icing	3 600	0	3½ after
	Second re-icing	5 600	0	33 after
	Third re-icing	1 800	0	47 after
	Total	20 000	0	

directly to the packing shed, where it was graded, packed, and later loaded into the car. Loading began at 2:30 p.m. and was completed at 3:30 p.m. the same day. During loading, one door on one side of the car was open almost continuously, as the entire car was loaded without interruption. The car was closed, sealed, and hauled to the holding yard as soon as the last of the fruit was in place. It moved out at 11:30 that night for Cleveland, Ohio.

The electrical resistance thermometers were placed in the fourth row, which was one of the two middle rows in the load. Taking of the initial temperature reading was delayed about one hour while the car was being moved to the holding yard. Temperature records were taken at 3- to 4-hour intervals during the first part of the test and at 8- to 10-hour intervals as the rate of cooling became slower.

Moderately warm weather prevailed during the morning while the fruit was being harvested. Later in the day the temperature rose

noticeably, and at 4:30 p.m. had reached 84° F. The sky was clear, and a light west breeze blew most of the day. The temperature of the fruit as placed in the car varied from about 70° F. to 75° F.

Rates of Cooling in the Two Cars. Table 1 shows the positions of the thermometers in Cars A and B. It also shows the initial thermometer readings in both cars and the rates of temperature drop at the various thermometer locations. Table 2 shows the quantities of ice supplied each car and the time intervals between re-icings.

Comparing the rates of cooling in six positions in each car, it is evident that the floor racks in Car B improved refrigeration in the middle and quarter-length positions in the car. Cooling was, however, about equal in the bottoms of the bunker stacks, and more rapid in the top of the bunker stack in Car A than in a similar position in Car B. An average of the six positions shows that the rate of cooling in Car B, with floor racks, was slightly superior to that in Car A, without floor racks.

The most noticeable effect of floor racks as indicated by these tests was greater uniformity of cooling thruout the load. In Car B fruit in the top and bottom layers of the door stack cooled at almost the same rate as similarly located fruit in the bunker stack. In Car A the fruit in the bunker stack cooled very rapidly, while that in both top and bottom layers of the door stack cooled very slowly. This would seem to indicate that air circulation toward the middle of the car was much better in Car B than in Car A. Since the end-to-end offset system of loading bushel baskets leaves no straight, uninterrupted air channels thru the load, no strong air circulation at the middle of the car should be expected in a car so loaded and not equipped with floor racks.

Retarded air circulation toward the middle of Car A apparently caused cold air from the bottom of the ice bunkers to move upward rather than toward the middle of the car. This accounts for the more rapid cooling of fruit in the top layer of the bunker stack in Car A than that in the bottom layer of the quarter length stack. When floor racks are used under a load of fruit packed in bushel baskets, cold air from the bunkers seems to flow with little interruption under the floor racks to the middle of the car. The two air currents meet and are forced upward thru the load by more air issuing from the bunkers. The fact that fruit in the bottom layer of the quarter-length stack in Car B cooled more slowly than similarly located fruit in the door stack suggests that circulation up thru the load from under the floor racks is greater at the middle of the car than at the quarter-length position.

Floor Racks Apparently Increase Air Circulation. These data tend to substantiate the idea that floor racks increase the circula-

tion of air thruout the load. They are in agreement with the results obtained by Pennington and other workers in the U. S. Department of Agriculture. Their work, however, was done for the most part with products packed in rectangular containers and loaded in a manner that provided air channels between the rows. Slightly different results might be expected with tightly loaded bushel baskets, but in both cases floor racks seem to have improved circulation toward the middle of the car.

Most railroad companies in the United States have realized the value of floor racks and are equipping with permanent floor racks all refrigerator cars not already so equipped.

Salt Apparently Increased Rate of Refrigeration

Numerous articles and publications have recommended adding salt to the ice in refrigerator car bunkers to hasten cooling of the lading. Pennington, Ramsey, and other workers in the U. S. Department of Agriculture have recommended this practice, altho they differ somewhat as to the amount of salt to be used.

Car B, With Floor Racks. Car B, as previously described, was a refrigerator car equipped with floor racks, loaded with 396 bushel baskets containing Elberta peaches, and shipped under standard refrigeration.

Car K, Salt Added to Ice Bunkers. Car K was similar to Car B in construction, equipment, and condition. It was initially iced with 9,000 pounds of ice and 180 pounds of salt about eight hours before loading was begun. It was spotted for loading at 11:00 a.m., and loading began at noon. Electrical resistance thermometers were placed in the third row, which was one of the two middle rows. The car contained 284 bushels of peaches at 6:00 p.m. when the first temperature reading was taken. It was held over night in that condition. The load was increased to 396 bushels the following morning before eleven o'clock.

The 284 baskets of peaches that were in the car at the end of the first day made four complete rows, with 20 baskets over. These 20 baskets were placed against the bunker in the same end of the car as were the thermometers. This made conditions in that half of the load more nearly comparable to a fully loaded car than in the opposite end, which contained only four complete rows. Since the thermometers were in the third row, which was flanked on both sides by baskets of fruit, and since that end of the car was fully loaded against the bunker, the conditions somewhat approximated those found in a fully loaded car. In making comparisons, however, it must be remembered that Car K was only partially filled during the first 15 to 18 hours of the test, and that the doors were opened for some time during the second 12-hour period to finish the loading.

TABLE 3.—COMPARISON OF TEMPERATURES IN DIFFERENT PARTS OF CAR B, UNDER STANDARD REFRIGERATION, AND CAR K, WITH SALT ADDED TO THE BUNKER ICE
(Both cars loaded with peaches)

Car	Thermometer positions			Starting temperature	Drop in temperature					
	Stack	Layer	Row		In 12 hours	In 24 hours	In 36 hours	In 48 hours	In 60 hours	In 72 hours
				° F.	° F.	° F.	° F.	° F.	° F.	° F.
B	Bunker	Bottom	Middle	67.5	14.0	22.2	25.8	28.3	30.5	31.1
K	Bunker	Bottom	Middle	85.0	22.1	34.8	38.7	42.5	46.3	48.5
B	Bunker	Top	Middle	73.0	4.2	10.5	14.8	19.3	21.8	23.7
K	Bunker	Top	Middle	82.0	13.0	16.3	21.2	26.1	31.0	33.0
B	Quarter-length	Bottom	Middle	71.5	11.8	19.8	23.5	26.5	28.0	29.4
K	Quarter-length	Bottom	Middle	85.0	21.2	29.3	33.2	37.0	40.8	43.5
B	Quarter-length	Top	Middle	73.0	5.8	12.5	16.3	20.7	22.9	24.5
K	Quarter-length	Top	Middle	85.0	16.3	23.3	26.9	31.4	35.9	38.5
B	Door	Bottom	Middle	72.5	13.7	20.8	25.9	28.5	30.2	31.1
K	Door	Bottom	Middle	83.5	18.3	26.3	30.0	33.7	37.4	39.6
B	Door	Top	Middle	72.0	3.2	7.7	11.8	16.2	19.2	21.2
K	Door	Top	Middle	84.0	13.8	19.4	23.7	27.9	32.2	34.5
B	Average	....	....	71.6	8.8	15.7	19.7	24.4	25.4	26.9
K	Average	....	....	84.1	17.8	25.0	29.2	33.4	37.5	39.9

The weather during the first day was hot and sultry, and the sky was cloudy during the afternoon. The thermometer registered 80° F. at 6:00 p.m. The temperature of the fruit entering the car averaged about 84° F. The following morning when loading was completed the air was clear and the temperature reached 91° F. at 11:30 a.m.

During the afternoon of the second day the car was moved from the team track and was started on its trip to St. Louis, Mo. Table 3 shows a comparison of the temperature drops in different parts of Car B with those in corresponding positions in Car K. A record of the amounts of ice supplied both cars, of the times at which the cars were iced, and of the amount of salt added to the ice in Car K is shown in Table 4.

Rates of Cooling in the Two Cars. In the tests here reported, Car K, in which 2 percent of salt was added to the ice at initial icing and at all re-icings, cooled its load much more rapidly in all positions

TABLE 4.—ICING RECORD OF CARS B AND K

Car	Icing	Ice	Salt	Time from first temperature reading
		lbs.	*lbs.*	*hrs.*
B	Initial	9 000	0	8 before
	First re-icing	3 600	0	3½ after
	Second re-icing	5 600	0	30½ after
	Third re-icing	1 800	0	47 after
	Total	20 000	0	
K	Initial	9 000	180	14 before
	First re-icing	7 200	144	24 after
	Second re-icing	4 200	84	65 after
	Total	20 400	408	

tested than did Car B, which moved under standard refrigeration. Both cars were loaded with bushel baskets of peaches.

The fact that the fruit in Car K cooled, on the average, twice as rapidly as that in Car B would seem to indicate that salt greatly improved refrigeration in this test. The correct and complete explanation of the phenomena observed is, however, somewhat more complicated than at first seems to be the case.

Pennington stated that in a well-constructed refrigerator car the air issues from the bunkers at about 34° F., and that this temperature drops about one degree, Fahrenheit, for every one percent of salt added to the ice at the initial icing. Air issuing from the bunkers in Car K was, therefore, probably about two degrees colder than that in Car B. The rate of heat transfer from the fruit to the air should vary directly with the rate of air movement and with the temperature difference between air and fruit. Little is known concerning the rate and direction of air circulation thruout the load and with-

in the baskets. But since methods of loading, types of packages, and lading were similar in the two cars, it seems reasonable to assume that air circulation was similar in both cars. The addition of salt to the ice in Car K may have caused a slight increase in the rate of air circulation thru increasing the temperature difference between the air entering the tops of the bunkers and that issuing from the bottom bunker openings. Higher temperature of the lading should produce a similar effect on air circulation. The temperature of the fruit in Car K averaged 13.5° F. higher than that in Car B at the beginning of the tests. Altogether, temperature differences between air and fruit were much greater in Car K than in Car B. Under such circumstances the more rapid refrigeration would be expected in Car K, especially during the first part of the test. But only a fraction of this effect can reasonably be attributed to the salt added to the ice.

Car K, as previously noted, was not completely loaded during the first twelve hours of the test, altho the load in the end containing thermometers was nearly completed when the test began. It seems doubtful that this condition could have been responsible for much of the nine degrees difference in average rates of cooling observed in these cars during the first twelve hours. Refrigeration in Car K was markedly slower the second twelve hours than during the first twelve hours of the test. Part of this effect was probably caused by the car door being opened twice to allow completion of the load. The remainder was probably due to the decreased temperature difference between air and lading.

Factors Responsible for More Rapid Cooling in Car K. Credit for the more rapid refrigeration of fruit in Car K than in Car B during the first twelve hours of the tests must be divided between the salt, the differences in fruit temperature, and the incomplete load in Car K. At the beginning of the second 24-hour period, fruit temperatures in these cars were more nearly equal and both cars were completely loaded. During the second and third days of the test Car K refrigerated its load, on the average, somewhat better than Car B. Probably most of this effect can be attributed to the salt added to the ice in Car K, altho differences in fruit temperatures probably contributed to the total effect. This test clearly shows that altho Car K cooled its lading much more rapidly than did Car B, 72 hours' time and 2 percent of salt were required to overcome the temperature advantage with which Car B began the test.

Use of Salt a Supplementary Measure. These results, viewed as a whole, seem to indicate that adding salt to the ice in a refrigerator car produces some increase in the rate at which that car will chill its lading. It is clear, however, that precautions taken to insure the fruit being as cool as possible when placed in the cars will be of

greater benefit in fruit transportation than any amount of salt that can safely be added to the bunker ice. Care during harvesting and packing to keep the fruit as cool as possible, and precooling whenever practicable, should be the practices relied upon to start the fruit to market at reasonably low temperatures. Adding salt to the ice may be viewed as an emergency measure to be used when efficient handling methods do not suffice to keep decay and overripeness in check

Adding Salt at Initial Icing Most Effective

Suggestions have been made that the proper time to add salt to the ice in the bunkers is when loading is practically completed. A comparison of the rates of refrigeration in Cars K and L throws some light on this question.

How Salt Was Added. In Car K salt was added at initial icing several hours before the loading of the car began; in Car L the salt was added when loading was practically completed.

The test on Car L was made about the middle of August, 1928. This car was similar in construction, condition, and equipment to Car K except that a small break in the outside layer of the wall was noted near one door. It is doubtful whether any considerable heat leakage could have taken place at that point.

Air temperatures were high during the day on which Car L was loaded. The thermometer registered over 90° F. during part of the afternoon. Three hundred ninety-six bushel baskets of Elberta peaches were loaded into this car according to the end-to-end offset system of loading, which was followed also in loading Car K. The peaches loaded into Car L varied from 80° F. to 85° F.

Car L was initially iced with 9,000 pounds of ice about seven hours before loading began. The car was spotted for loading during the morning, and the first baskets of peaches were put in place about 11:00 a.m. Loading was finished at 2:30 p.m., and the car was then billed to a city in western Illinois. At 2:15 p.m. 180 pounds of coarse salt were added to the ice in the bunkers. The salt was dumped on top of the ice and partly worked in with an iron bar. The billing specified standard refrigeration, so no more salt was added to the ice during the trip.

Car K received 180 pounds of salt at initial icing and was not re-iced until 26 hours after the first temperature record was taken. Car L, as noted above, received 180 pounds of salt after loading was practically completed, and was not re-iced for more than 24 hours after the first temperature record was taken. The rates of cooling in these cars during the first 24 hours may then be considered as indicating the value of adding salt after loading has been completed, as compared with salting at initial icing.

TABLE 5.—COMPARISON OF TEMPERATURES IN DIFFERENT PARTS OF CAR K, SALTED AT INITIAL ICING, AND CAR L, SALTED AT TIME LOADING WAS COMPLETED

(Both cars loaded with peaches)

Car	Thermometer positions			Starting temperature	Drop in temperature				
	Stack	Layer	Row		In 6 hours	In 12 hours	In 24 hours	In 36 hours	In 48 hours
				° F.	° F.	° F.	° F.	° F.	° F.
K	Bunker	Bottom	Middle	85.0	11.0	22.1	34.8	38.7	42.5
L	Bunker	Bottom	Middle	80.0	11.4	18.0	29.7	35.3	39.8
K	Bunker	Middle	Middle	86.0	10.5	21.2	28.0	33.0	37.9
L	Bunker	Middle	Middle	79.5	10.5	16.5	27.2	32.8	37.3
K	Bunker	Top	Middle	82.0	6.5	13.0	16.3	21.2	26.1
L	Bunker	Top	Middle	83.0	3.4	9.0	16.3	22.2	28.3
K	Quarter-length	Bottom	Middle	85.0	10.5	21.2	29.3	33.2	37.0
L	Quarter-length	Bottom	Middle	80.0	8.0	13.9	24.0	29.3	34.0
K	Quarter-length	Middle	Middle	84.0	9.1	17.1	22.0	27.0	32.2
L	Quarter-length	Middle	Middle	80.5	5.7	9.9	17.2	23.8	28.4
K	Quarter-length	Top	Middle	85.0	9.7	16.3	22.3	26.9	31.4
L	Quarter-length	Top	Middle	87.0	4.7	9.6	18.5	24.1	29.3
K	Door	Bottom	Middle	83.5	9.1	18.3	26.3	36.0	33.7
L	Door	Bottom	Middle	76.0	9.6	14.3	23.2	28.1	30.9
K	Door	Middle	Middle	82.0	7.6	14.0	20.3	25.2	30.0
L	Door	Middle	Middle	81.0	5.8	10.9	20.4	26.4	31.0
K	Door	Top	Middle	84.0	6.1	13.8	19.4	23.7	27.9
L	Door	Top	Middle	83.0	7.3	11.6	19.8	25.5	30.6
K	Average	....	....	84.1	9.1	17.6	24.4	29.3	33.3
L	Average	....	....	82.2	7.1	12.3	21.3	27.1	31.8

Comparative Rates of Cooling. The comparative rates of cooling of the fruit in the bottom, middle, and top layers in Cars K and L are shown in Table 5. The complete icing records for both cars are shown in Table 6. Since neither of these cars was re-iced for over 24 hours after loading was completed, the rate of cooling in the two cars during the first 24 hours of the tests may be taken as indicative of the comparative value of adding salt at the two different times. The advantage in this case seems to be altogether in favor of Car K, in which salt was added at the initial icing. The average drop in temperature during the first twelve hours was five degrees more in Car K than in Car L. After 24 hours the average temperature drop was over three degrees more than in Car L, altho Car K had been opened twice for loading during that period.

At the end of 24 hours, fruit in the top and middle layers of the door stack in Car L had cooled very slightly more than fruit

TABLE 6.—ICING RECORD OF CARS K AND L

Car	Icing	Ice	Salt	Time from first temperature reading
		lbs.	*lbs.*	*hrs.*
K	Initial	9 000	180	14 before
	First re-icing	7 200	144	24 after
	Second re-icing	4 200	84	65 after
	Total	20 400	408	
L	Initial	9 000	180	Ice—10½ before Salt at first temperature reading
	First re-icing	7 200	0	31½ after
	Second re-icing	4 200	0	51½ after
	Total	20 400	180	

in similar locations in Car K. In all other positions where records were taken, Car K had cooled as rapidly as, or more rapidly than, Car L. The average temperature drop was 3.1° F. more in Car K than in Car L.

It is reasonable to suppose that since salting the bunker ice lowers the temperature of the air issuing from the bunkers, the addition of salt at initial icing would result in the car being more thoroly chilled by the time loading started than if no salt were used. Therefore, more rapid cooling of the lading could be expected in a car salted several hours before loading than in one to which salt was added after loading was completed.

Floor Racks More Beneficial Than Salt in Refrigerating Strawberries

An indication of the relative value of floor racks and of 2 percent salt added to the ice is shown by a comparison of the rates of refrigeration of strawberries in Car C (salted with 2 percent salt at

loading time but not equipped with floor racks) and Car H which was equipped with floor racks but in which no salt was used.

Car C, Without Floor Racks. The test on Car C was run during the early part of June, 1927. The car was loaded at a southern Illinois shipping point with 420 crates of Aroma strawberries. This car was similar in construction and condition to those previously described. It was not, however, equipped with floor racks.

Car C was initially iced with 9,000 pounds of ice early in the morning, and was sent to the loading point by local freight. Loading took place between 11:15 a.m. and 4:15 p.m. The 24-quart ventilated crates were loaded four layers high and seven rows wide, with eight stacks in the head end of the car and seven in the opposite end. Lath strips were placed between the layers of crates in each stack to prevent shifting of the crates from side to side. The strips were not nailed to the crates but were held in place only by the weight of the crates resting on them.

Electrical thermometers were placed in the middle row and in one side row in the head end of the car as the crates were set in place.

The air temperature during the day was moderate, being only 75° F. at 4:30 p.m. The humidity was high, and there was very little or no air movement. The temperature of the fruit as loaded in the car was from 62° to 68° F., with most of it about 65° F. The berries were high in water content due to a very heavy rain the night before.

At 4:00 p.m., just before loading was completed, 200 pounds of salt were added to the ice in the bunkers. At 4:30 the car was sealed and shipped under standard refrigeration with 2 percent salt at all re-icings. The car moved out for Pittsburgh, Pennsylvania, as soon as it was sealed and billed. Temperature records within the car were taken at frequent intervals during the trip.

Car H, With Floor Racks. A temperature test on Car H was conducted late in May, 1928. This car was similar to Car C in condition and construction, but, unlike Car C, it was equipped with permanent floor racks.

Nine thousand pounds of ice were placed in Car H early in the morning. It was then sent to the loading track. Loading began at 2:00 p.m. and was completed at 4:35 p.m. The lading consisted of 420 24-quart crates of Klondike strawberries loaded four layers high, seven rows wide, with eight stacks in the head end and seven stacks in the other end. As the crates were loaded, lath strips were placed between the layers of crates in each stack, but as in Car C, the laths were not nailed to the crates. Electrical resistance thermometers were placed in the middle row and in one wall row in the head end of the car.

During the day on which Car H was loaded the sky was clear and a light north breeze was blowing most of the day. The air tem-

perature during the day was moderate. At 5:00 p.m., when the car was closed and sealed, the thermometer registered 75° F. The temperature of the berries as loaded into the car averaged about 68° F. The car was moved for Chicago under standard refrigeration about 6:00 p.m. Temperature tests were taken at frequent intervals during the trip.

Comparative Rates of Cooling. The temperature drops which occurred in both Car C and Car H are shown in Table 7.[a] Table 8 gives a complete record of the ice and salt supplied.

During the first 12 hours of these tests the middle row in Car C cooled very slightly faster than the same row in Car H. After 24 hours, however, the fruit temperatures in Car H had, as an average, dropped 2.6° F. more than those in Car C. This difference had increased to 3.8° F. after 36 hours had elapsed. In the side rows the differences were not as marked, but were slightly in favor of Car H. Examination of the temperature drops recorded at various positions in both cars indicates that during the first 12 hours Car C was in some places refrigerating more rapidly than Car H, and less rapidly in others. The averages for that period show that Car C cooled very slightly faster than Car H. During the second 12 hours, however, Car H refrigerated its load noticeably better than Car C in most of the positions. This condition continued thru the third 12-hour period.

Floor racks, therefore, appear to be more beneficial in improving refrigeration under the conditions of these tests than does the addition of 2 percent salt to the ice at the time of loading and at all re-icings.

Refrigeration Retarded by Heavy Loading

Loading bushel baskets of fruit four tiers high resulted in less favorable refrigeration than loading only three tiers high.

Car A, Three Tiers High. Car A, as previously described, was loaded with 396 bushels of Elberta peaches and was shipped under standard refrigeration. It was not equipped with floor racks. The end-to-end offset system of loading was used, making the load 22 baskets long, 6 wide, and 3 high.

Car E, Four Tiers High. Car E, which was similar to Car A in construction, equipment, and condition, was loaded with 528 bushels of Yellow Transparent apples packed in bushel baskets. The load was 22 baskets long, 6 wide, and 4 high. The car was iced at

[a]After the second temperature reading had been taken, the thermometer in the top layer of the bunker stack in Car H ceased to function. In Tables 7 and 8 the record for a position in the same stack and layer but in the row against the wall has been used for that position. The difference in fruit temperature at these two points was probably small at all times.

TABLE 7.—COMPARISON OF TEMPERATURES IN DIFFERENT PARTS OF CAR C, WITH SALT BUT NO FLOOR RACKS, AND CAR H, WITH FLOOR RACKS BUT NO SALT

(Both cars loaded with strawberries)

Car	Thermometer positions: Stack	Layer	Row	Starting temperature	Drop in temperature: In 12 hours	In 24 hours	In 36 hours
				° F.	*° F.*	*° F.*	*° F.*
C	Bunker	Bottom	Middle	57.5	20.5	24.2	25.5
H	Bunker	Bottom	Middle	66.0	19.9	26.1	29.2
C	Bunker	Top	Middle	68.0	6.2	14.3	18.5
H	Bunker	Top	Side[1]	67.0	1.9	10.0	15.8
C	Quarter-length	Bottom	Middle	60.0	16.5	22.7	23.6
H	Quarter-length	Bottom	Middle	69.5	20.4	27.2	30.2
C	Quarter-length	Top	Middle	67.0	4.5	11.7	16.0
H	Quarter-length	Top	Middle	71.0	4.2	13.2	19.3
C	Door	Bottom	Middle	68.0	14.8	20.1	23.1
H	Door	Bottom	Middle	67.0	19.3	25.5	26.1
C	Door	Top	Middle	67.5	9.8	15.1	18.9
H	Door	Top	Middle	71.0	3.8	14.2	19.3
C	Average	......	......	64.7	11.7	17.8	20.7
H	Average	......	......	68.6	11.8	19.6	23.7
C	Bunker	Bottom	Side	57.0	16.9	22.0	24.5
H	Bunker	Bottom	Side	66.0	20.8	25.7	28.2
C	Bunker	Top	Side	68.5	8.6	16.2	20.0
H	Bunker	Top	Side	67.0	1.9	10.0	15.8
C	Quarter-length	Bottom	Side	66.0	21.0	26.3	28.0
H	Quarter-length	Bottom	Side	70.0	17.7	24.9	27.7
C	Quarter-length	Top	Side	67.0	6.3	13.8	18.0
H	Quarter-length	Top	Side	70.5	7.8	16.2	21.3
C	Door	Bottom	Side	60.0	13.0	18.0	18.4
H	Door	Bottom	Side	69.0	17.3	23.2	25.7
C	Door	Top	Middle[2]	67.5	9.8	15.1	18.9
H	Door	Top	Side	70.0	9.4	15.1	18.2
C	Average	......	......	64.3	12.9	18.9	21.7
H	Average	......	......	68.8	12.6	19.5	23.2

[1]See footnote on page 533.

[2]The tests on Car C were run after one of the thermometers was out of commission, and there were not enough thermometers to include tests in all the positions. Hence, for comparison, temperatures taken in the middle row of the top layer of the door stack are used in place of temperatures in the side row, which were lacking.

TABLE 8.—ICING RECORD OF CARS C AND H

Car	Icing	Ice	Salt	Time from first temperature reading
		lbs.	*lbs.*	*hrs.*
C	Initial	9 000	200	Ice—12½ before Salt—½ before
	First re-icing	3 000	60	22½ after
	Second re-icing	1 800	36	45 after
	Total	13 800	296	
H	Initial	9 000	0	13 before
	First re-icing	4 200	0	12½ after
	Total	13 200	0	

3:00 p.m. and was spotted for loading at 5:40 p.m. Loading began immediately. By 6:50 p.m. 400 bushels of apples were stowed in place. Four rows were completed lengthwise and the other two rows in the head end of the car were finished as far as the quarter-length position. Electrical thermometers were placed in the head end of the car thruout the third row. The car was held over night in that condition.

About 9:15 a.m. the next day the car was opened for a short time while the load was completed. The doors were then closed and sealed, but the car was held at the loading point for 32 hours before it was shipped. Late in the afternoon of the third day it was sent under standard refrigeration to Buffalo, New York. Temperature readings within the car were taken at frequent intervals while the car was on the loading track and in transit.

During the day on which loading was begun air temperatures were moderate. The thermometer registered 76° F. at 11:00 a.m., and 74° F. at 6:45 p.m. There was very little air movement, and the sky was clear. The temperature of the fruit as placed in the car averaged about 72° F.

Comparative Rates of Cooling. The rates of cooling of the fruits in these two cars are shown comparatively in Table 9. Table 10 is a record of the ice supplied both cars during the tests.

Car E, loaded with summer apples 4 tiers high, contained 33⅓ percent more fruit by volume than Car A, loaded with peaches 3 tiers high, but only about 20 percent more fruit by weight, on account of the difference in weight of a bushel of apples and a bushel of peaches.[a] The fruit in Car E averaged somewhat higher in temperature than that in Car A, so might normally be expected to cool somewhat more rapidly, especially during the first few hours.

The bottom layer of the bunker stack was the only position in Car E that cooled more rapidly than similar positions in Car A during the first 12 hours. After 24 hours the bottom layers of the quarter-length and door stacks in Car A also showed greater temperature drops than similar positions in Car E.

Top Layers Show Greatest Differences in Cooling. The most striking difference between similarly located positions in the two cars was in the top layers of the bunker stacks. The relatively slow cooling at this point in Car E indicates very slow air circulation at that point. In Car A the top layer of the bunker stack cooled, on the whole, more rapidly than the bottom layer in the quarter-length position. In Car E the bottom layer of the quarter-length position cooled over twice as rapidly as the top layer against the bunker. In the top layer in the quarter-length stack of Car A

[a]There is no difference in the specific heat of apples and of peaches.

the temperature drop was 4° F. less during 36 hours than in the bottom layer of the door stack. Temperatures in the top layer of the quarter-length position in Car E dropped 8.9° F. less in 36 hours than did those in the bottom of the bunker stack.

Air Circulation Slow in High Loading. These facts taken as a whole suggest that when bushel baskets are loaded 4 layers high,

TABLE 9.—COMPARISON OF TEMPERATURES IN DIFFERENT PARTS OF CAR A, LOADED WITH PEACHES THREE BASKETS HIGH, AND CAR E, LOADED WITH APPLES FOUR BASKETS HIGH

Car	Thermometer positions			Starting temperature	Drop in temperature		
	Stack	Layer	Row		In 12 hours	In 24 hours	In 36 hours
				° F.	*° F.*	*° F.*	*° F.*
E	Bunker	Bottom	Middle	71.5	16.7	26.0	30.3
A	Bunker	Bottom	Middle	64.5	14.8	21.8	25.2
E	Bunker	Top	Middle	72.0	5.0	8.3	11.5
A	Bunker	Top	Middle	69.5	9.3	19.9	26.8
E	Quarter-length	Bottom	Middle	71.0	8.4	17.0	22.2
A	Quarter-length	Bottom	Middle	68.0	10.0	15.2	19.2
E	Quarter-length	Top	Middle	72.5	2.9	6.1	8.1
A	Quarter-length	Top	Middle	67.5	3.2	6.8	10.7
E	Door	Bottom	Middle	73.5	8.7	14.3	17.0
A	Door	Bottom	Middle	69.0	8.6	11.7	14.7
E[1]	Door	Top	Middle	....	....	....	....
A[1]	Door	Top	Middle	71.5	3.2	5.7	9.5
E	Average (5 positions)	......	......	72.1	7.6	13.5	17.1
A	Average (5 positions)	......	......	67.7	8.4	13.9	18.1

[1]Not figured in the average.

TABLE 10.—ICING RECORD OF CARS A AND E

Car	Icing	Ice	Salt	Time from first temperature reading
		lbs.	*lbs.*	*hrs.*
E	Initial	9 000	0	3¾ before
	First re-icing	7 200	0	64½ after
	Second re-icing	3 000	0	83 after
	Third re-icing	3 200	0	106 after
	Fourth re-icing	3 400	0	132 after
	Total	25 800	0	
A	Initial	9 000	0	11 before
	First re-icing	6 000	0	14½ after
	Second re-icing	1 800	0	30½ after
	Total	16 800	0	

air circulation up thru the load is very slow. Air from the bunkers, of course, flows where there is the least resistance. In Car E this seemed to be along the floor between the baskets.

Rapid cooling of the load as a whole necessitates open air channels thru the load both horizontally and vertically. It would seem, therefore, that bushel baskets loaded 4 layers high by the end-to-

end offset system cannot be refrigerated rapidly in the upper layers. The remedy for this difficulty may lie in the use of packages which may be loaded in a manner that will allow proper air circulation thruout the load. Since overripeness in the upper layers is one of the chief reasons for rejection of summer apples arriving on the market, this problem merits serious consideration.

TABLE 11.—COMPARISON OF TEMPERATURES IN DIFFERENT PARTS OF CAR B, LOADED WITH BUSHEL BASKETS OF PEACHES, AND CAR H, LOADED WITH CRATES OF STRAWBERRIES

Car	Thermometer positions			Starting temperature	Drop in temperature		
	Stack	Layer	Row		In 12 hours	In 24 hours	In 36 hours
				° F.	° F.	° F.	° F.
B	Bunker	Bottom	Middle	67.5	14.0	22.2	25.8
H	Bunker	Bottom	Middle	66.0	19.9	26.1	29.2
B	Bunker	Top	Middle	73.0	4.2	10.5	14.8
H	Bunker	Top	Side[1]	67.0	1.9	10.0	15.8
B	Quarter-length	Bottom	Middle	71.5	11.8	19.8	23.5
H	Quarter-length	Bottom	Middle	69.5	20.4	27.2	30.2
B	Quarter-length	Top	Middle	73.0	5.8	12.5	16.3
H	Quarter-length	Top	Middle	71.0	4.2	13.2	19.3
B	Door	Bottom	Middle	72.5	13.7	20.8	25.9
H	Door	Bottom	Middle	67.0	19.3	25.5	26.1
B	Door	Top	Middle	72.0	3.2	7.7	11.8
H	Door	Top	Middle	71.0	3.8	14.2	19.3
B	Average	......	......	71.6	8.8	15.7	19.7
H	Average	......	......	68.6	11.8	19.6	23.9

[1]See footnote on page 533.

TABLE 12.—ICING RECORD OF CARS B AND H

Car	Icing	Ice	Salt	Time from first temperature reading
		lbs.	lbs.	hrs.
B	Initial	9 000	0	8 before
	First re-icing	3 600	0	3½ after
	Second re-icing	5 600	0	33 after
	Third re-icing	1 800	0	47 after
	Total	20 000	0	
H	Initial	9 000	0	13 before
	First re-icing	4 200	0	12½ after
	Total	13 200	0	

Rectangular Ventilated Packages Permit Better Refrigeration Than Bushel Baskets

Cars B and H Compared. The effect of package type upon the rate of cooling of fruit in refrigerator cars is illustrated by the temperature records on Car B and Car H. Altho Car B contained about 20,000 pounds of peaches in bushel baskets and Car H about

17,000 pounds of strawberries in rectangular ventilated crates, some idea of the effects of differences in package type may be gained from a comparison of the temperature drops in the two cars. The difference in the specific heat of the two fruits—.91 for strawberries as compared with .92 for peaches—is too slight to merit consideration here.

Car B, as previously described, was equipped with floor racks, and was loaded with 396 bushels of peaches. Car H was similar to Car B in construction, equipment, and condition, but was loaded with 420 crates of strawberries.

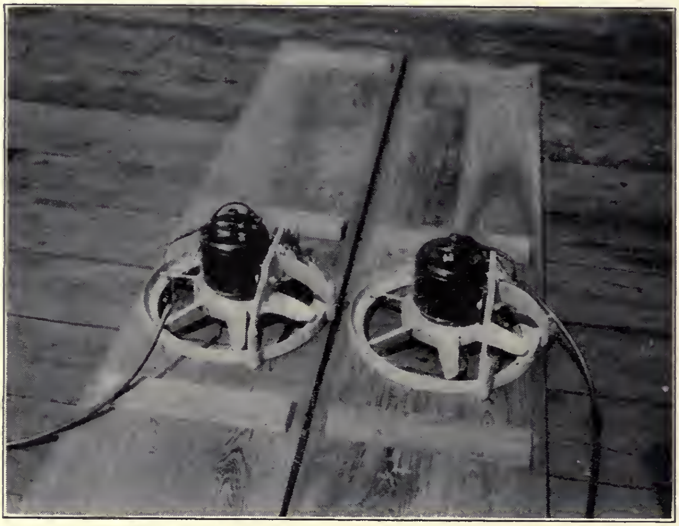

FIG. 4.—ELECTRIC FANS USED TO FORCE AIR CIRCULATION IN A REFRIGERATOR CAR

Power for operating these fans was secured from the city lighting system.

Table 11 shows the comparative rates of cooling observed in the top and bottom layers of these cars. Table 12 gives the complete icing records for the test trips on both cars.

The rate of cooling in the bottom layer of the bunker stack was much more rapid in Car H than in Car B, especially during the first 12 hours. This was probably due mainly to the construction of the strawberry crate. This package permits air circulation around and thru the small boxes containing the berries, while a well-made bushel basket probably allows very little air circulation around the fruit itself.

The more rapid temperature drops observed at the quarter-length and door positions in Car H were probably due in part to the better ventilation in the strawberry crates. Temperatures in the top layers of both the quarter-length and door stacks in Car H dropped more rapidly than those in similar positions in Car B. Part of this was probably due to the differences in ventilation thru the two types of packages, and part to the improved air circulation around the strawberry crates. Air channels between the rows of crates allow

FIG. 5.—ELECTRICAL FAN MOUNTED ON A BOARD READY FOR INSTALLATION IN A REFRIGERATOR CAR

uninterrupted air movement thru the load and therefore more rapid refrigeration in the top layer.

Forced Air Circulation Increased Rate of Cooling

Because of the influence which the air circulation thruout a refrigerator carload of fruit has on the rate of fruit cooling, it was thought that cooling might be hastened by electric fans operated within the car. A test was therefore made on a carload of peaches (Car M). Temperature changes in this car were compared with those in Car K, which was handled under similar conditions except that no fans were used.

Car K, Without Fans. Car K, as previously described, was a refrigerator car equipped with permanent floor racks and loaded with 396 bushels of Elberta peaches. It was shipped under standard refrigeration with 2 percent salt at initial icing and at all re-icings.

TABLE 13.—COMPARISON OF TEMPERATURES IN DIFFERENT PARTS OF CAR K, UNDER STANDARD REFRIGERATION PLUS SALT, AND CAR M, UNDER SAME REFRIGERATION BUT EQUIPPED WITH ELECTRIC FANS

(Both cars loaded with peaches)

Car	Thermometer positions			Starting temperature	Drop in temperature						
	Stack	Layer	Row		In hours	In 12 hours	In 24 hours	In 36 hours	In 48 hours	In 60 hours	In 72 hours
				° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F
K	Bunker	Bottom	Middle	85.0	11.0	22.1	34.8	38.7	42.5	46.3	48.5
M	Bunker	Bottom	Middle	74.0	15.8	20.2	26.5	31.9	36.3	38.6	40.6
K	Bunker	Top	Middle	82.0	6.5	13.0	16.3	21.2	26.1	31.0	33.0
M	Bunker	Top	Middle	84.0	16.0	18.1	23.1	27.0	30.8	34.2	37.0
K	Quarter-length	Bottom	Middle	85.0	10.5	21.2	29.3	33.2	37.0	40.8	43.5
M	Quarter-length	Bottom	Middle	74.0	11.0	15.2	21.7	26.8	30.8	33.4	35.7
K	Quarter-length	Top	Middle	85.0	9.7	16.3	22.3	26.9	31.4	35.9	38.5
M	Quarter-length	Top	Middle	87.0	12.5	16.3	23.0	28.2	32.8	36.3	39.4
K	Door	Bottom	Middle	83.5	9.1	18.3	26.3	30.0	33.7	37.4	39.6
M	Door	Bottom	Middle	73.0	13.3	17.8	22.5	27.3	31.1	33.3	34.9
K	Door	Top	Middle	84.0	6.1	13.8	19.4	23.7	27.9	32.2	34.5
M	Door	Top	Middle	80.5	6.0	9.8	15.7	20.7	25.5	29.4	32.7
K	Average	....	....	83.1	9.1	17.8	25.0	29.2	33.4	37.5	39.9
M	Average	....	....	78.8	12.3	16.1	22.2	25.9	31.4	34.4	36.9

Car M, With Fans. Car M was a refrigerator car, similiar in construction, condition, and equipment to Car K. It also was loaded with 396 bushels of Elberta peaches packed in bushel baskets and stowed according to the end-to-end offset system.

Car M was iced early in the morning and was spotted for loading at 8.00 a.m. At 8:30 two electrically-driven four-bladed propeller fans were placed in the car. (Fig. 4.) Two boards of the proper size were firmly fastened over the openings above the bulkheads. These boards effectively prevented air circulation thru these openings except thru a hole thirteen inches in diameter in the middle of each board. The fans were placed over these holes and fastened to the boards. (Fig. 5.) When in motion the fans drew air from above the lading, and forced it down thru the bunkers and out the lower bulkhead openings. Power was brought to the fans thru wires entering the car between the door and the door frame.

Loading was begun at 9:30 a.m. The third row of baskets was put in place about 10 o'clock. Electrical resistance thermometers were placed in selected locations in one half of that row. The fans were started at 3:00 p.m. after four rows of baskets were in place. They were stopped for a few minutes at 4:00 p.m. and at 5:00 p.m., while more fruit was being placed in the car. Three hundred nine bushels were in the load at 5:20 p.m., making four rows the length of the car and completing the other two rows from the bunker past the quarter-length position in the end containing thermometers. The fans were run from that time until 7:00 p.m. when they were turned off for the night. Between 9:00 and 9:45 the following morning the load was completed. The fans were run from 9:50 to 11:50 a.m., at which time they were removed and the car was sealed. This car was billed to Pittsburg, Kansas, under standard refrigeration with 2 percent salt at all re-icings.

The weather during the day on which the test started was relatively hot, with a moderate south wind. The thermometer registered 89° F. at 3:00 p.m. During the following day the maximum temperature recorded was 86° F. The temperature of the fruit as placed in the car averaged about 79° F.

Comparative Rates of Cooling. Temperature records were taken at two-hour intervals while the fans were in motion. After the fruit had been cooled somewhat, the rate of cooling diminished and the intervals between temperature readings were lengthened. The temperature drops at various positions in Cars K and M are shown in Table 13. Icing records for these cars are shown in Table 14.

The temperature drops observed the first 6 hours, during which time the fans in Car M were operated most of the time, averaged more than 3 degrees faster in Car M than in Car K. The effect of the fans was particularly noticeable in the top layers of the bunker and quarter-length positions.

During the following 6 hours the fans and boards were left in position but the fans were not operated. This seems to have effectively retarded normal air circulation. The average temperature drop during the second 6 hours of the tests was only 3.9° F. in Car M as compared to 8.3° F. in Car K. During the second 12 hours of the test the fans were operated for 2 hours, but were then removed because the ice supply in the car was quite low. The shortage of ice during that period resulted in slightly less cooling in Car M than in Car K during the second 12 hours. After Car M was re-iced, cooling proceeded at about the same rate in both cars. Cooling in Car M finally became a little slower than in Car K, probably because its original fruit temperature average was 5 degrees lower than that in Car K.

TABLE 14.—ICING RECORD OF CARS K AND M

Car	Icing	Ice	Salt	Time from first temperature reading
		lbs.	*lbs.*	*hrs.*
K	Initial	9 000	180	14 before
	First re-icing	7 200	144	24 after
	Second re-icing	4 200	84	65 after
	Total	20 400	408	
M	Initial	9 000	180	10 before
	First re-icing	7 000	140	26 after
	Second re-icing	2 400	48	39½ after
	Third re-icing	1 000	20	70 after
	Total	19 400	388	

Top Layers Most Affected by Fans. It is of interest to note that the greatest increases in cooling produced by the fans were in the top layer of the car. Cooling is usually relatively slow thruout the top layer. The possibility of this layer being cooled several degrees before the car is shipped is encouraging. The effect of forced air circulation on the car as a whole, as represented by the temperature drop observed during the first 6 hours of these tests, suggests that the use of fans by shippers of highly perishable fruits may be worth while. The results obtained are certainly promising enough to justify further investigations regarding the value of this practice.

SUMMARY AND CONCLUSIONS

1. Data showing the rates of refrigeration in transit of eight cars of peaches, strawberries, and apples shipped under various conditions are presented and discussed.

2. Floor racks improved to some extent the rate of cooling in a refrigerator car loaded with peaches, and caused greater uniformity of refrigeration thruout the load.

3. Peaches loaded in refrigerator cars at relatively low temperatures and shipped under standard refrigeration reached safe carrying temperatures sooner than peaches loaded at higher temperatures and shipped under standard refrigeration with 2 percent of salt added to the bunker ice at initial icing and at all re-icings. Salt increased to some extent the rate of refrigeration within the car. The data indicate, however, that precautions taken to insure the fruit being as cool as possible when placed in the car are of greater benefit in fruit transportation than any amount of salt that can safely be added to the bunker ice.

4. Two percent of salt added to the bunker ice at the initial icing several hours before loading proved more beneficial in improving the refrigeration of peaches than did 2 percent of salt added to the ice after loading was completed.

5. Floor racks were more beneficial in refrigerating strawberries in transit than 2 percent of salt added to the bunker ice at loading time and at all re-icings.

6. Bushel baskets of fruit loaded four layers high according to the end-to-end offset system of loading were found to refrigerate very slowly, especially in the top layer, under normal shipping conditions. The results obtained indicate that poor air circulation thruout the load was in this case the chief cause of inefficient refrigeration.

7. Fruit in packages which allowed good air circulation around the fruit itself and rapid air movement thruout the entire load cooled more rapidly than fruit in tight packages loaded so that air circulated with difficulty thru the load.

8. Electrically driven fans were used to increase the rate of air circulation in a refrigerator car loaded with peaches. Results obtained show that refrigeration was improved thereby, and suggest that further investigations along these lines are desirable.

9. Little or no information concerning the direction and rate of air movement within refrigerator cars and within the fruit packages is available at present. Careful and extensive studies of these points seem necessary for a complete understanding of refrigeration in transit.

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